Signals and Circuits

ENGR 35500

Transistor

Chapter 17: 17-1 (DC operation of bipolar junction transistor)(pp. 781-785)

Floyd, T. L., and Buchla, D. M., *Electroics Fundamentals: Circuits, Devices & Applications*, 8th Edition, Pearson, 2009.

Chapter 3: 3-7 (Application Note: Bipolar Junction Transistor)(pp. 127-130)

Ulaby, Fawwaz T., and Maharbiz, Michael M., *Circuits*, 2nd Edition, National Technology and Science Press, 2013.

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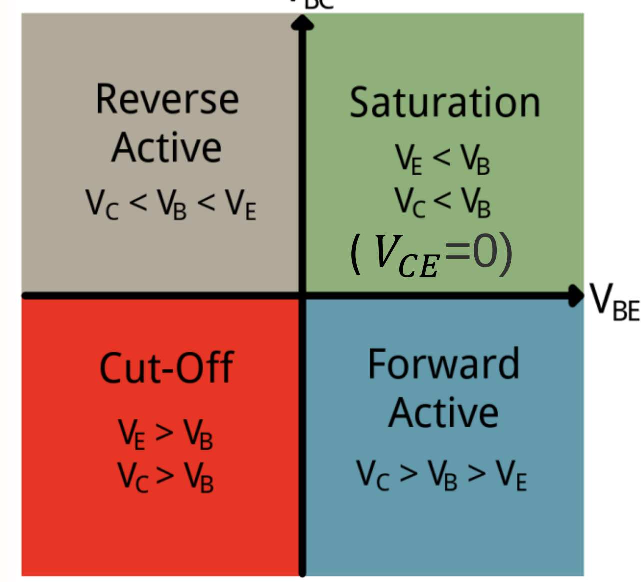
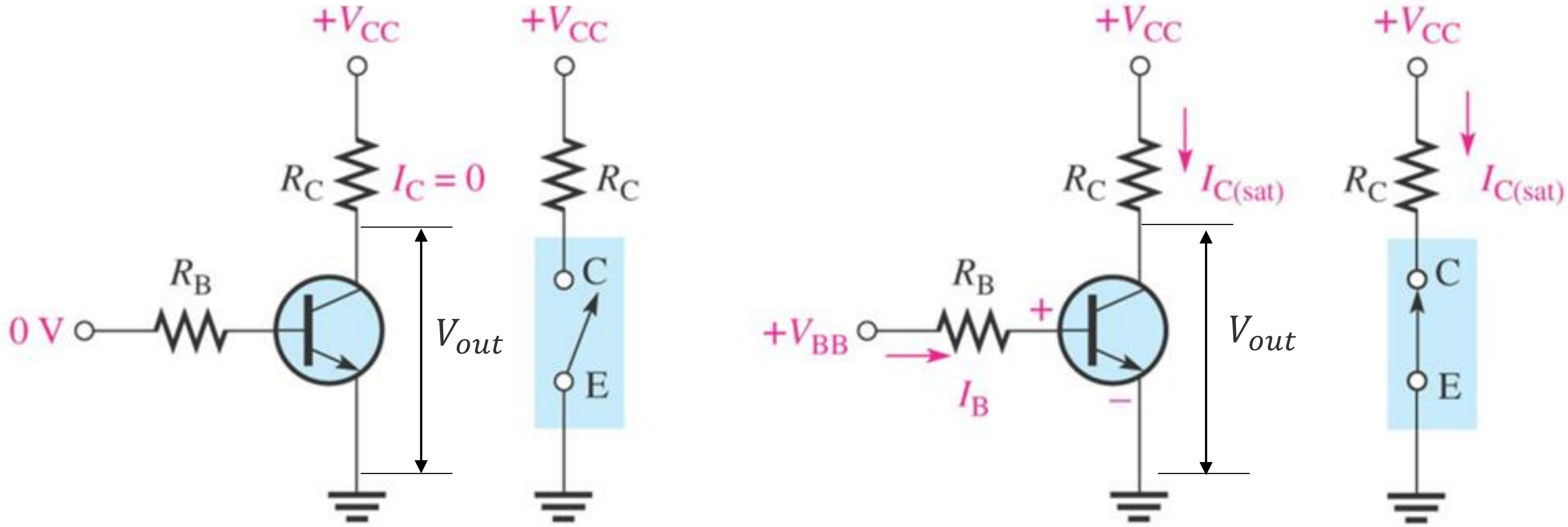
Transistor application

BJT as a switch



When used as an electronic switch, a transistor normally is operated alternately in cutoff and saturation

- A transistor is in cutoff when the base-emitter junction is not forward-biased. V_{CE} is approximately equal to V_{CC}
- When the base-emitter junction is forward-biased and there is enough base current to produce a maximum collector current, the transistor is saturated



(a) Cutoff — open switch

(b) Saturation — closed switch

$$V_{CE} = V_{CC}$$
$$I_C = 0$$

$$V_{CE} = 0V$$
$$I_C = V_{CC}/R_C$$

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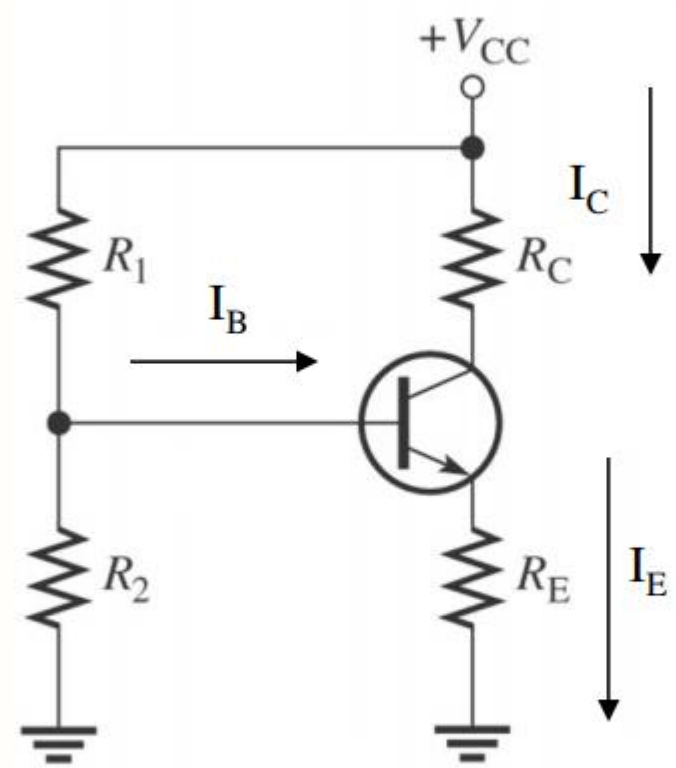
DC Operation of BJTs (active region)

The base voltage is aproximately: $V_B \approx \left(\frac{R_2}{R_1 + R_2}\right)V_{CC}$ (I_B *is very small*)



Emitter voltage and Current

$$V_E = V_B - 0.7V$$

$$I_E = V_E / R_E$$

$$I_C = \beta I_B$$

$$I_E \approx I_C$$

Collector voltage: $V_C = V_{CC} - I_C R_C$

$$V_{CE} = V_C - V_E$$

V_B *denotes the voltage between the base terminal to the ground.*

V_C *denotes the voltage between the collector terminal to the ground.*

V_E *denotes the voltage between the emitter terminal to the ground.*

DC Operation of BJTs

NOTE: The base voltage is aproximately: $V_B \approx \left(\frac{R_2}{R_1+R_2}\right)V_{CC}$

Emitter voltage and Current

$V_E = V_B - 0.7V$

$I_E = V_E / R_E$

$I_C = \beta I_B$

$I_E \approx I_C$

$I_B = I_C / \beta$

Collector voltage: $V_C = V_{CC} - I_C R$

$V_{CE} = V_C - V_E$

$E.g.$

Determine $V_B, V_E, V_C, I_B, I_E, I_C$ *in the Figure, as* $\beta = 200,\ R_1 = 22k\Omega,\ R_2 = 10k\Omega,\ R_C = 1.0k\Omega,\ R_E = 1.0k\Omega,\ V_{CC} = 30V$

$$V_B = \frac{R_2}{R_1 + R_2} \times V_{cc} = \frac{10}{22+10} \times 30 = 9.375V$$

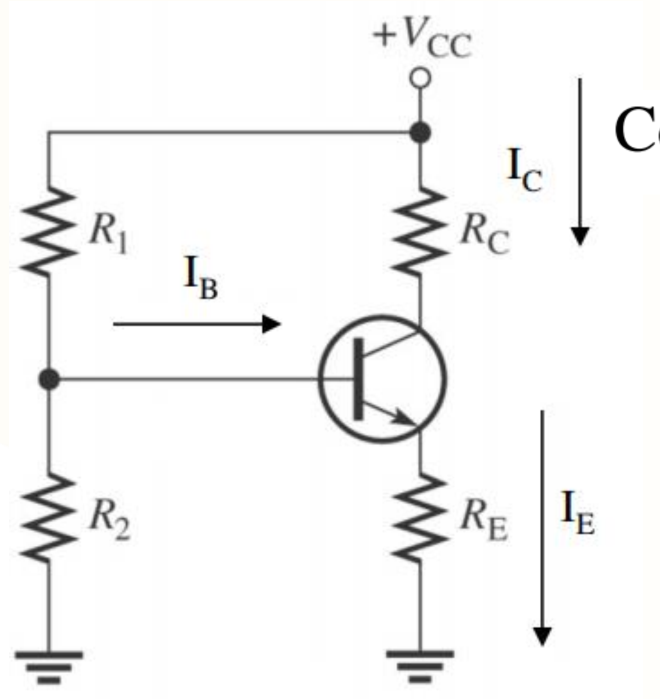
$$V_E = V_B - 0.7V = 8.675V$$

$$I_E = \frac{8.675V}{1kohm} = 8.675mA$$

$$I_C \approx I_E = 8.675\text{mA}$$

$$I_B = I_C/\beta = \frac{8.675mA}{200} = 43.375\mu A$$

$$V_C = V_{CC} - I_C R_C = 30 - 8.675mA \times 1kohm = 21.325V$$



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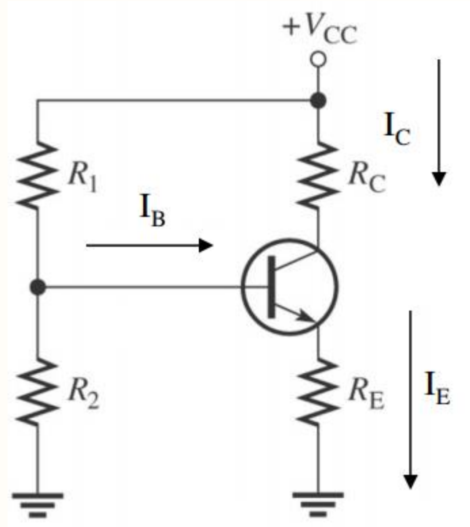
BJT Class A signal amplifiers

A **common-emitter** (CE) amplifier

- capacitors are used for coupling ac without disturbing dc levels

The base voltage is aproximately: $V_B \approx \left(\frac{R_2}{R_1+R_2}\right) V_{CC}$

Emitter voltage and Current



$$V_E = V_B - 0.7V$$

$$I_E = V_E / R_E$$

$$I_C = \beta I_B$$

$$I_E \approx I_C$$

$$I_B = I_C/\beta$$

Collector voltage: $V_C = V_{CC} - I_C R_C$

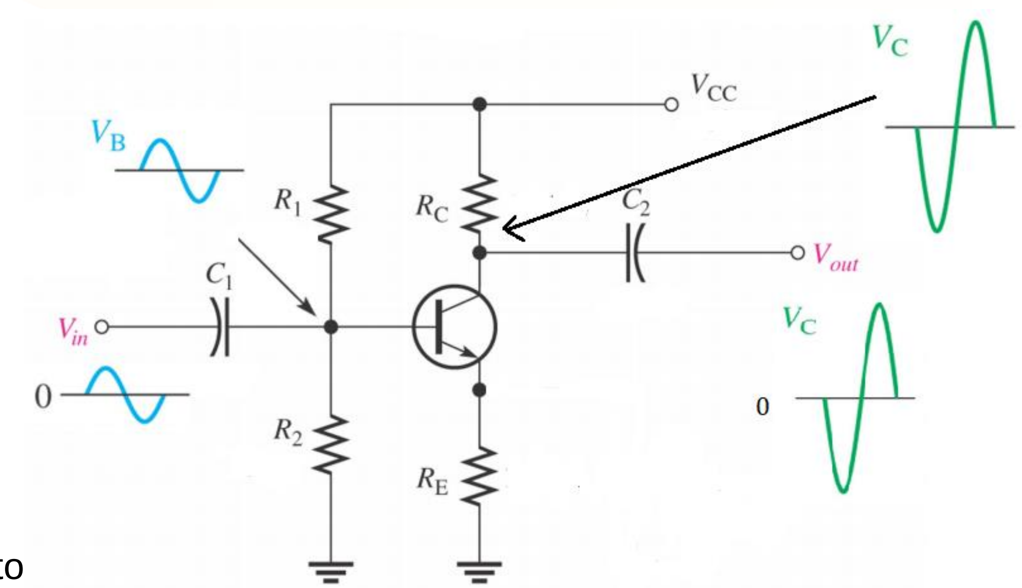
$$V_{CE} = V_C - V_E$$

Signal voltage gain A_v

$$A_v = \frac{\Delta V_C}{\Delta V_B} \approx \frac{\Delta V_c}{\Delta V_E} = -\frac{\Delta I_C R_C}{\Delta I_E R_E} = -\frac{R_C}{R_E}$$

This is only magnitude gain.

Actually, the phase is shifted by 180 degree.



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BJT Class A signal amplifiers

E. G.

In the figure, a signal voltage of 50 mV rms is applied to the base.

(a) Determine the output signal voltage rms for the amplifier

(b) Find the dc collector voltage on which the output signal voltage is riding

(c) Draw the output waveform.

(a) The signal voltage gain is

$$A_v \cong \frac{R_C}{R_E} = \frac{10\ \text{k}\Omega}{1.0\ \text{k}\Omega} = 10$$

The output signal voltage is the input signal voltage times the voltage gain.

$$V_{out} = A_v V_{in} = (10)(50\ \text{mV}) = \mathbf{500\ mV\ rms}$$

(b) Next find the dc collector voltage.

$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{4.7\ \text{k}\Omega}{51.7\ \text{k}\Omega}\right)25\ \text{V} = 2.27\ \text{V}$$

$$I_C \cong I_E = \frac{V_E}{R_E} = \frac{V_B - 0.7\ \text{V}}{1.0\ \text{k}\Omega} = 1.57\ \text{mA}$$

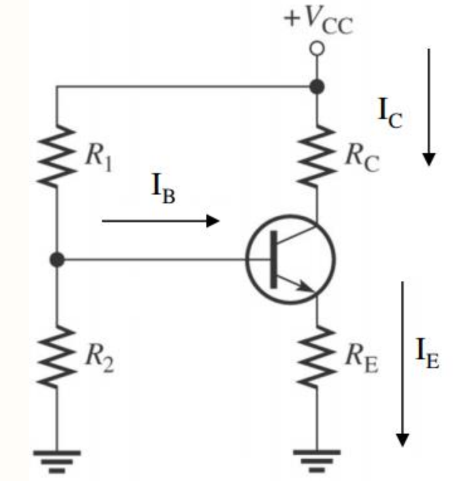
$$V_C = V_{CC} - I_C R_C = 25\ \text{V} - (1.57\ \text{mA})(10\ \text{k}\Omega) = \mathbf{9.3\ V}$$

(c) This value is the dc level of the output. The peak value of the output signal is

$$V_p = 1.414(500\ \text{mV}) = 707\ \text{mV}$$

The base voltage is aproximately: $V_B \approx \left(\frac{R_2}{R_1 + R_2}\right)V_{CC}$

Emitter voltage and Current



$$V_E = V_B - 0.7V$$

$$I_E = V_E / R_E$$

$$I_C = \beta I_B$$

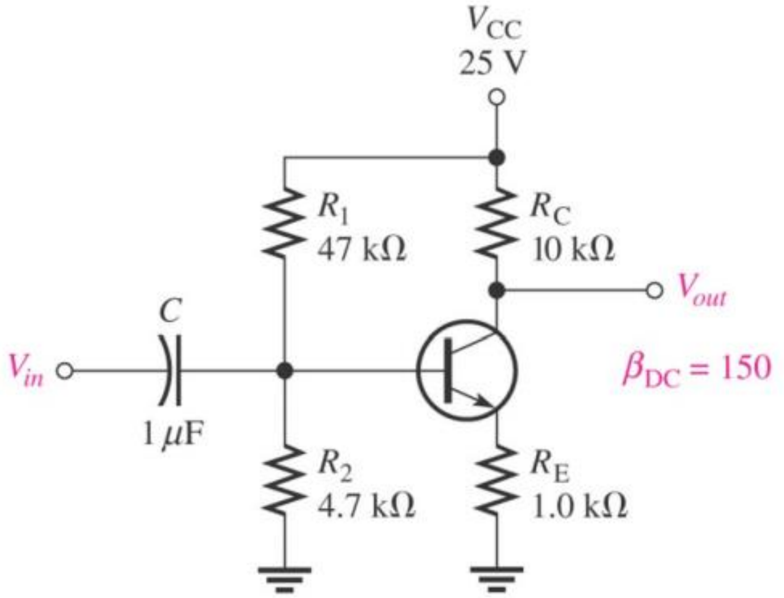
$$I_E \approx I_C$$

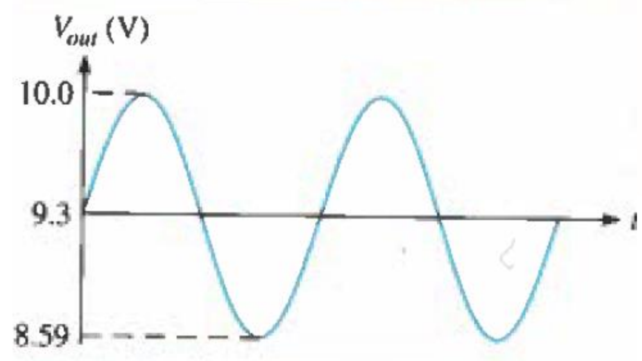
$$I_B = I_C / \beta$$

Collector voltage: $V_C = V_{CC} - I_C R_C$

$$A_v = \frac{\Delta V_C}{\Delta V_B} \approx \frac{\Delta V_c}{\Delta V_E} = -\frac{R_c}{R_E}$$

$$V_{CE} = V_C - V_E$$





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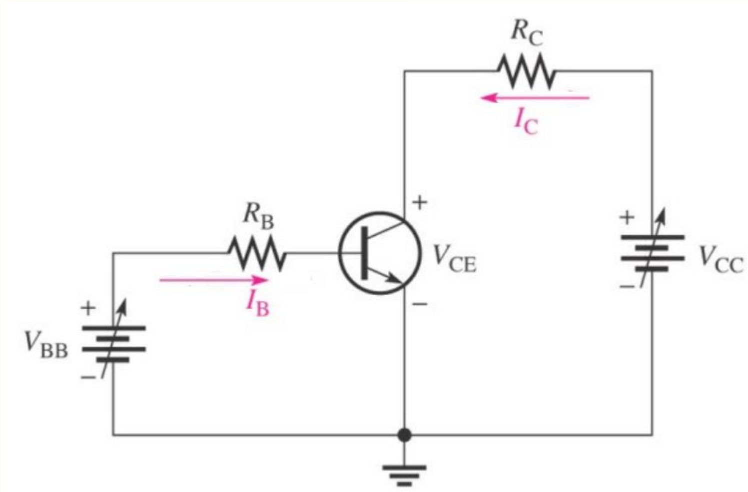
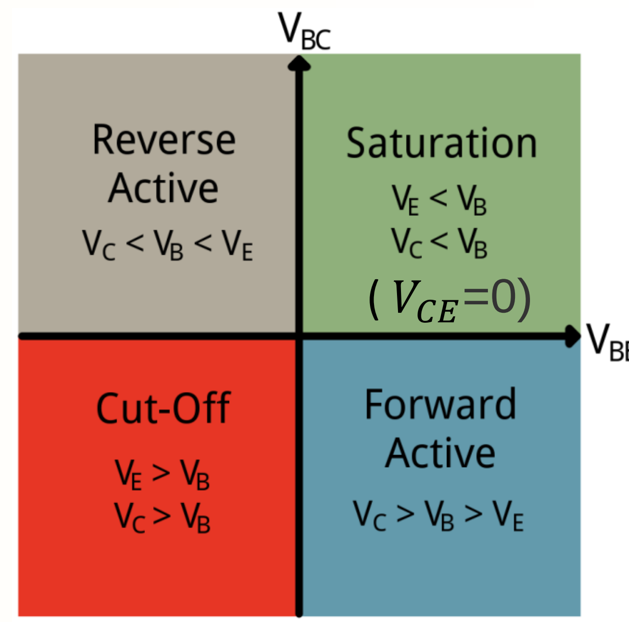
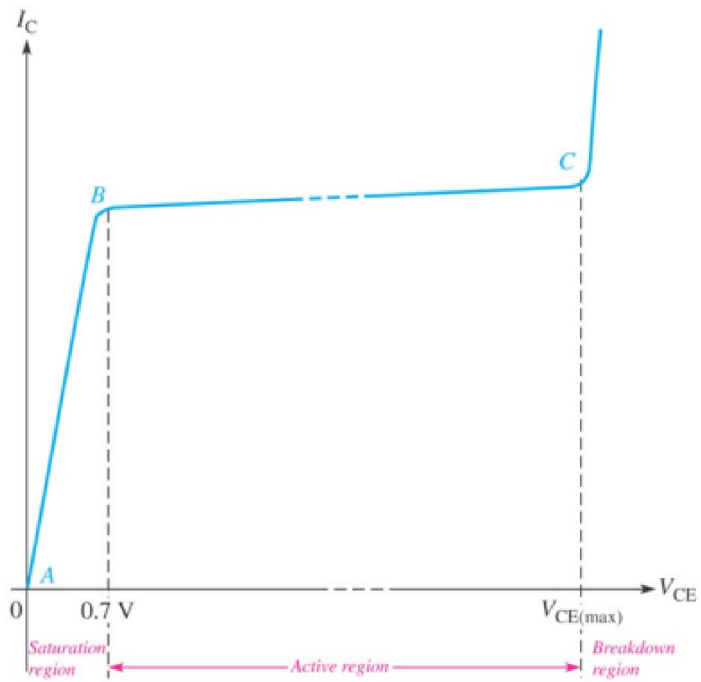
Region variation



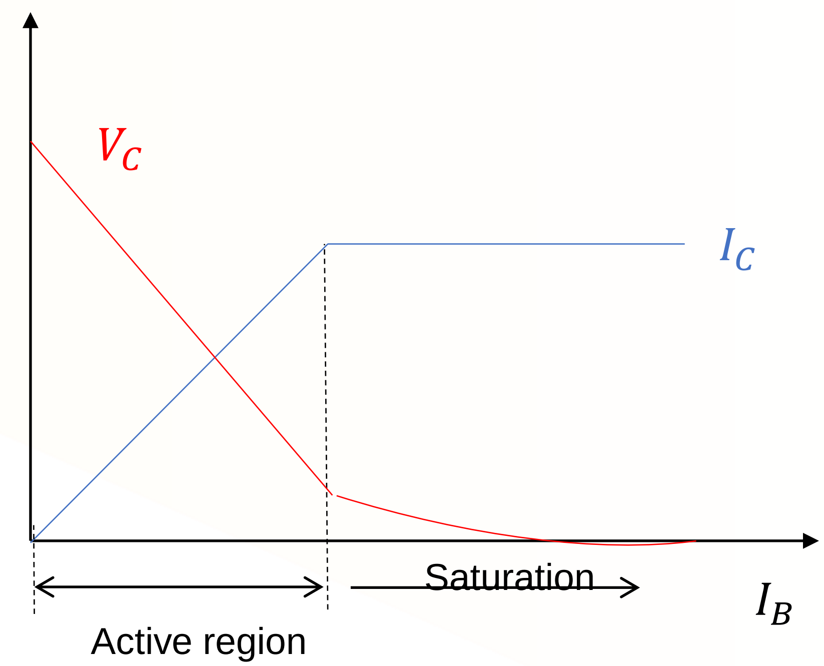


Fixed V_{BB}, *and then increase* V_{CC}:



I_C versus V_{CE} curve for one value of I_B

Fixed V_{CC}, *and then increase* V_{BB}:



$$V_C = V_{CC} - I_C\, R_C = V_{CC} - \beta I_B\, R_C$$

V_{CE} can not be negative

V_{CE} is zero in saturation region

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